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Water-supply infrastructure of Byzantine Constantinople

Kate Ward, James Crow and Martin Crapper

Introduction

Modern water-supply systems – hidden beneath the ground, constructed, expanded, adapted and repaired intermittently by multiple groups of people – are often messy and difficult to comprehend. The ancient water-supply system we consider here is no different - and perhaps even more complex as it was developed over 1200 years and then had a modern city built on top. Despite this, we are beginning to understand how one of the Roman world's most important cities provided its population with water.

The remains of water infrastructure in Constantinople attest to a complex system of water-management and distribution, one that developed from the colony of Byzantium, through the growth and eventual decline of the new capital of the Roman empire, until conquest by the Ottomans. Aqueducts -- the system of channels, bridges and tunnels designed to carry water through the landscape -- were the focus of infrastructure investment in earlier periods, but cisterns for the storage and distribution of water were constructed throughout the time of Byzantine Constantinople. While recent archaeological studies have ensured a better understanding of the key elements of the system,¹ they have not investigated how the water was distributed within the city. The present study, part of the research programme "Engineering the Byzantine water supply: procurement, construction and operation", aims to apply contemporary civil engineering techniques to elucidate city's hydraulic infrastructure.² Much of our knowledge of hydraulic delivery and distribution in ancient urban settings derives from cities such as Pompeii and Ephesos where the infrastructure is accessible,³ rather than from Rome or Istanbul where modern development obscures the ancient city.⁴ By adopting an engineering perspective, we aim to counter the fragmentary nature of the archaeological evidence, integrating the scattered evidence into a functional whole.

The water supply in Constantinople had three distinct elements: two aqueducts (the Hadrianic Line and the Valens Line) and cisterns of varying sizes throughout the city; this use of cisterns as a major

¹ C. Mango, "The water supply of Constantinople," in id. and G. Dagron (edd.) *Constantinople and its hinterland* (Aldershot 1995) 9-18; K. Çeçen, *The longest Roman water supply line* (Istanbul 1996); J. Crow, J. Bardill and R. Bayliss 2008, *The water supply of Byzantine Constantinople* (London 2008).

² A parallel study is considering the application of construction management techniques to determine the processes of construction and issues concerning procurement and the workforce; see J. R. Snyder, L.C. Stephenson, J.E. Mackie and S.D. Smith, "Agent-based modelling and the Byzantine: understanding the construction of antiquity's largest infrastructure project," in P.W. Chan and C.J. Neilson (edd.), *Proc. 32nd Annual ARCOM [Assoc. of Researchers in Construction Management] Conference* (Manchester 2016) vol. 2, 963-72.

³ Cf. D. Keenan-Jones, "Somma-Vesuvian movements and the water supply of Pompeii and the Bay of Naples," *AJA* 119 (2015) 191-215 for a recent study of Pompeii; for the ceramic pipe network from Ephesos and how distribution changed over time, cf. J. Pickett, "Temples, churches, cisterns and pipes: water in late antique Ephesus," in G. Wiplinger (ed.), *De aquaeductu atque aqua urbium Lyciae Pamphylicae Pisidiae* (BABesch Suppl. 27) 297-312 – in contrast to other more traditional aqueduct studies in S Turkey reported in the same volume.

⁴ See the integrated study from Roman Barcelona, albeit on a lesser scale: H.A. Orenego and C. Miró i Alaix, "Reconsidering the water system of Roman Barcino (Barcelona) from the supply to discharge," *Water History* 5 (2013) 243-66.

component of the supply system is singular, if not unique, in Roman municipal water supplies.⁵ The available evidence varies across the three elements. Since the Hadrianic Line has no physical evidence and very few references in historical texts; we have to build up a picture of the line using what can be inferred from the topography of Constantinople and the known and likely users of this water line; we can also make inferences from the Ottoman supply system, which is thought to have made use of the same water source in the Belgrade Forest. There is more physical evidence of the Valens Line although its interpretation is uncertain, particularly along the ancient main street, the Mese. For cisterns, the evidence is both physical and textual, previous studies having provided detailed descriptions and dating of some, but we will arrive at considerably more cisterns than has been supposed by comparing and combining the two most recent and comprehensive studies. While our understanding of how the elements of the water-supply system evolved and operated is still at an early stage, the work detailed here provides a springboard for further investigation and clarifies the questions that can be asked about the Byzantine city's water supply.

Background

Constantinople was an important new city with a water problem. Despite the strategic advantages of its location, the city that became the capital of the Roman Empire was soon compared to a beautiful woman bedecked with jewels but thirstier "than those who are dressed in rags".⁶ To tackle the issue, the city undertook several challenging construction projects which added water-supply infrastructure to the existing 2nd-c. Hadrianic Line of Roman Byzantium. Within a few decades of Constantinople's foundation, engineers constructed the Valens Line to tap distant springs in the Thracian hinterland. An initial study, identifying and mapping this far-reaching aqueduct, estimated the length of channel to be 292 km, but more recently studies have calculated much greater distances.⁷ The initial research on the Valens Line was followed by extensive fieldwork which identified two distinct phases of aqueduct building:⁸ the first, dated to the mid-4th c., collected water from sources some 65 km from the city; the second, dated early to mid-5th c., came from sources around 120 km away, yet the straight-line distances do not give a clear picture of the scale of construction and the most recent investigation calculates the length to be at least 426 km, possibly as much as 564 km.

However, it would appear that even these substantial infrastructure investments were insufficient to supply the growing city. In the mid-5th c., with construction of the second phase of the Valens Line under way, the city altered its strategy and started to construct major cisterns within the walls.⁹ With at least 8 large public baths,¹⁰ the city may appear to follow the Roman model of extravagant water use, but the way in which the water-supply system developed and evolved points to a shortage in local water

⁵ For a review of Roman and Byzantine cisterns in the E Mediterranean region, see C.A. Stewart, "The modular design of Early Byzantine cisterns and reservoirs," in *Against gravity* (a symposium held in March 2015 at the University of Pennsylvania; prior to publication it is available at <http://www.sas.upenn.edu/ancient/publications.html>). In *Du Nil à Alexandrie: histoire d'eaux* (Paris 2011), I. Hairy provides an important study of the river-filled cisterns of Alexandria ranging in date from the Roman to the Islamic.

⁶ Themist. *Or.* 11.151a-152b, quoted in Crow, Bardill and Bayliss (supra n.1), 224.

⁷ Çeçen (supra n.1). In *Construction requirements of the water supply of Constantinople and Anastasian Wall* (Ph.D. diss., Univ. of Edinburgh 2013) 199, J.R. Snyder, based on re-analysis of the line drawn in Crow, Bardill and Bayliss (supra n.1), gives 454km.

⁸ Crow, Bardill and Bayliss *ibid.* 26-27.

⁹ The first major cistern recorded was the Modestiaca, in 363-369. Its location is uncertain, although it is possibly associated with the Saraçhane cistern identified by P. Forchheimer and J. Strzygowski, *Die Byzantinischen Wasserbehälter von Konstantinopel* (Vienna 1893) 52.

¹⁰ M. Mundell Mango, "Thermae, balnea/loutra, hamams: the baths of Constantinople," in P. Magdalino, and N. Ergin (edd.), *Istanbul and Water*, (Anc. Nr. East. Studies, Suppl. 47; Leuven 2015) fig. 12 with pp. 138-144.

supplies. The investment in and protection of the water-supply system should be viewed as critical to the city's success.

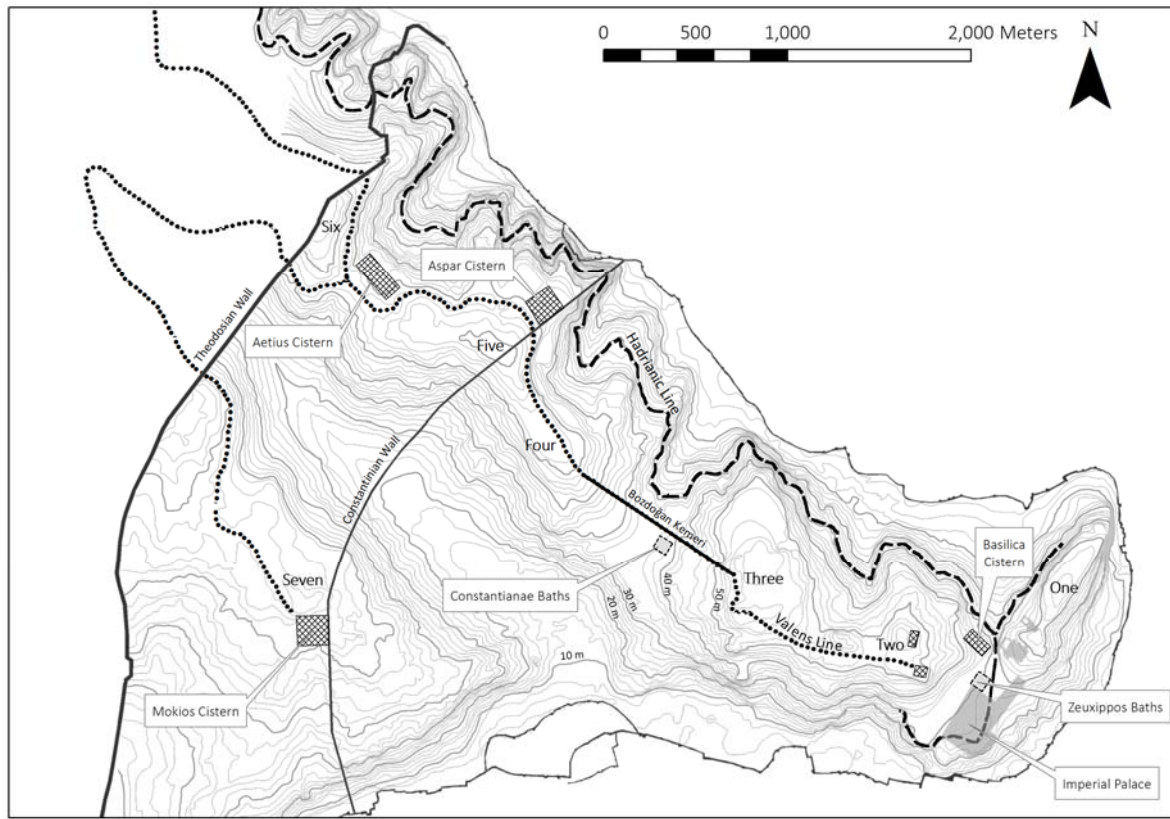


Figure 1: Original aqueduct routes proposed by Crow, Bardill and Bayliss 2008 (supra n.1). The Hadrianic Line is dashed; the Valens Line is dotted (image is adapted from the original data).

Current understanding of the three main elements of the water supply system

Prior to the present study, little work had been done considering water-supply at a system-wide level. The first attempt to map the two aqueduct lines within the city was made by J. Crow, J. Bardill and R. Bayliss.¹¹ In that study, Bayliss projected the Hadrianic Line based on access to the Basilica Cistern.¹² The modern contours of the city were utilized to trace the line back towards the Theodosian Wall. The route followed the north flanks of Hills Two, Three, Four, Five and Six and crossed the Wall at an elevation of about 35 masl). There are some inconsistencies between their written description of this route and what is illustrated.¹³ In the illustrated route shown by the dashed line in fig. 1, the line is at a low point of 24 m asl in the vicinity of the Basilica Cistern before climbing *uphill* to cross the platform between Hills One and Two to the Imperial Palace. We conclude that the route suggested is too low to supply water to the Imperial Palace, and would only be able to fill the Basilica Cistern to a depth of about 3 m.

The Valens Line (shown by the dotted line in fig. 1) was drawn by Bayliss based on the location and orientation of the Bozdoğan Kemer (the 970-m-long bridge spanning Hills Three and Four that still stands in Istanbul), the modern contours, and the location of some of the larger cisterns.

¹¹ Crow, Bardill and Bayliss (supra n.1) 110-124.

¹² The Hadrianic Line is associated with the Basilica Cistern at Mal., *Chron.* 18.17, and *Chron. Pasc.* 618-19, (both quoted in Crow, Bardill and Bayliss 232).

¹³ Crow, Bardill and Bayliss *ibid.* maps 12-15, 114-117.

In the study of 2008, Bardill compiled a bibliographic concordance of cisterns, detailing 161 examples that were identified and discussed in the literature. His work is complemented by the recent work of K. Altuğ who, with the aid of the Istanbul municipal archive (Koruma Bolge Kurulu), compiled a catalogue of 158 cisterns.¹⁴ Both these works considerably expanded the number of cisterns known, but even recent articles continue to underestimate the significance of cisterns in the city.¹⁵

1. Aqueduct of Hadrian

Before it became Constantinople, Byzantium was fed by an aqueduct constructed under Hadrian¹⁶ in the 2nd c. This aqueduct was the main water-provider for the city of Constantinople until 373 when the Valens Line started bringing water in. Although no recognisable traces of the Hadrianic Line survive, it continued to serve an important rôle within the Byzantine city; the law codes from c.440 restrict the use of the aqueduct to “the public, hot and cold baths and [the imperial] palace”; in the 6th c., the Hadrianic Line is associated with the construction of the Basilica Cistern.¹⁷

Water Supply to Byzantium

Given that the Hadrianic Line served the city for such a long period of time, it is worth considering the form of the town that the aqueduct originally supplied. That the aqueduct was operated, repaired and maintained for such a long period indicates that the channel was still relatively accessible despite the enormous changes taking place around the coastline and to the peninsula's topography. The original town occupied the end of the peninsula that would become Constantinople, bounded by a defensive wall that crossed the second hill from coast to coast,¹⁸ with the focus probably in the N-facing valley between Hills One and Two around the harbour and Strategion (now occupied by Sirkeci Station). This area is relatively low lying and could be served by an aqueduct arriving at c.31 m asl. Conventionally, water provided by Roman aqueducts would be distributed from the highest point of the town, maximising the area supplied. For Byzantium, this would have been at c.55 m asl, at the point which later became the Forum of Constantine. To achieve this, the Hadrianic Line would require a major bridge or inverted siphon to cross the valley between Hills Three and Four (where the Bozdoğan Kemer stands), but no evidence has been found or is attested in ancient accounts. If the population of Byzantium was concentrated on the lower slopes, a crossing structure, both costly and (since it exposed a vital lifeline into the town) a security weakness, may have been considered unnecessary. Nonetheless, it is likely that the builders aimed for as high an entry point to the town as practical, making the crossing of the valley between Hills Three and Four critical. As the lowest ground level of this valley is estimated to have been c.35-36 m asl in the Byzantine period,¹⁹ a probable maximum invert level (lowest point of the channel or pipe in cross-section) at this point is 34 m asl, assuming a cut-and-cover type construction rather than a method which would expose the channel above ground, making it vulnerable to tampering.

¹⁴ In *İstanbul'da Bizans Dönemi Sarnıçlarının Mimari Özellikleri ve Kentin Tarihsel Topografyasındaki Dağılımı*. (Ph.D. diss., İstanbul Teknik Üniversitesi 2013), K. Altuğ documented physical remains that he visited and those no longer extant, which others have investigated.

¹⁵ In “Use of cisterns during antiquity in the Mediterranean region for water resources sustainability,” *Water Science and Technology: Water Supply* 14 (2014) 38-47, L. Mays gives the number of cisterns in Constantinople as 70.

¹⁶ See Crow, Bardill and Bayliss (supra n.1) 10-13 on attributing the aqueduct to Hadrian.

¹⁷ *CJ* 11.42.6; Mal., *Chron.* 18.17, both quoted in Crow, Bardill and Bayliss *ibid.* 227, 232.

¹⁸ C. Mango, *Le développement urbain de Constantinople (IVe-VIIe siècles)* (Paris 1985) 14.

¹⁹ The level from W. Müller-Wiener's (*Bildlexikon zur Topographie Istanbul's* [Tübingen 1977]) older map, using the contours of the 1920s, is 41 m asl. In sounding B R.M. Harrison *Excavations at Saraçhane in Istanbul* (Princeton, NJ 1986) 13-14, found the foundations of Bozdoğan Kemer to be 6.5 m below the existing ground level.

Supplying the Imperial Palace and Zeuxippos Baths

When we come to early Constantinople, the law code from 440 states that the Hadrianic Aqueduct fed, amongst other sites, the Imperial Palace²⁰ which was located on the S side of the platform between Hills One and Two. The maximum ground level is c.30 m asl where the palace lies adjacent to the Hippodrome and Zeuxippos Baths, with ground levels falling to the south and east, so that if the channel was at a level sufficient to supply the platform level it would have been capable of supplying the Imperial Palace. Although there is no text linking the Zeuxippos Baths and the Hadrianic aqueduct, it appears clear that this is how the baths were supplied with water, which adds further evidence to the route of the aqueduct within the city; the Zeuxippos Baths, a centrepiece of the city, would have required access to an aqueduct to provide sufficient water.²¹ The Baths' origins are unclear, some texts attributing the baths to Severus and others to Constantine, But in either case they are undoubtedly an early feature of the city and should therefore be linked to the Hadrianic, not the Valens Line.²² The baths lie adjacent to the Hippodrome at a level of 30 m asl,²³ dropping slightly to the east. If this is the ground level in the baths, we would expect the water-supply to arrive at a higher level - at least 32 m asl - to allow it to flow through boilers, operate fountains and possibly showers.

Supplying the Constantianae Baths

It is less clear-cut but still possible that the Hadrianic Line may also have supplied, or been intended to supply, the Constantianae Baths which are believed to lie near the modern Belediye building²⁴ in the valley between Hills Three and Four. Construction of these baths began in 345 whereas the aqueduct of Valens did not arrive at the city until 373, and it is implausible that construction would start so far in advance of the water-supply on which the baths were reliant. Even the time to conceive, design and build the enormous Caracalla baths in Rome was no more than 7 years.²⁵ It seems more likely that the baths were constructed only where an adequate supply of water could be guaranteed, and when construction started, this could only have been the Hadrianic Line. In the event, however, the baths were not completed until 427. The 80-year construction period is extraordinary and must cast some doubt on the Hadrianic Line being the eventual supplier to the working baths. Still, whatever the circumstances of the baths' construction, we must consider the baths being fed by the Hadrianic Line as a strong possibility; the alternative is a bath that was intended to have been completed sat unused and empty for 20 years before the arrival of the Valens Line. Accepting, then, that the Hadrianic Line was capable of supplying the Constantianae Baths means that the channel crossed the valley between Hills Three and Four at a relatively high level. This opens up the possibility that the channel crossed the saddle of the valley and followed a course on the southern flanks of Hills Two and Three.

The comparative evidence of the Ottoman System

The generally held view is that the source of the Aqueduct of Hadrian was water from the Belgrade Forest north of the city. The same region would be used by the Ottomans for the water-supply line known as Kırkçeşme. If the Ottoman system exploits the same source and (as possible traces of older structures in bridges on the Kırkçeşme Line suggest) a similar route into the city, an examination of the

²⁰ *CJ* 11.42.6, quoted in Crow, Bardill and Bayliss (supra n.1) 227.

²¹ As A.T. Hodge, *Roman aqueducts & water supply* (2nd edn. London 2002) 000 said, many Roman aqueducts were constructed in order to supply public baths; a more convenient, flowing supply was merely a side benefit. Cf., e.g., the restoration of the *Aqua Marcia* and construction of the branch *Aqua Antoniniana* for the Baths of Caracalla: J. DeLaine, *The Baths of Caracalla* (JRA Suppl. 25 1997) 16.

²² Mundell Mango (supra n.10)136.

²³ S. Casson, D. Talbot Rice and A.H.M. Jones, *Preliminary report upon the excavations carried out in the Hippodrome of Constantinople in 1927 on behalf of the British Academy* (London 1928) 21.

²⁴ C. Mango (supra n.18) 41.

²⁵ DeLaine (supra n.21) 183.

newer system should provide insights into the older system.²⁶ Maps show the route the later system took within the city and identify fountains and control towers²⁷ which we can use to examine the water level during Ottoman times and which can serve as a proxy for the Hadrianic Line. The Ottoman system operated as a locally pressurised system, with water being driven through pipes by gravity between control towers called *suterazi*; thus a series of inverted siphons distributed water through the city. This system would allow water to overcome localised obstructions and changes in level.²⁸ As the system was still operating under gravity, however, the overall water level dropped as it was moving from upstream to downstream. This meant that fountains and other structures with a free water surface (i.e. not under pressure within a pipe) could not be at a higher elevation than the free water surface further upstream.

The maps of the Kırkçeşme system are puzzling. The crossing point near the Theodosian wall is at c.34 m asl, and photographs indicate that the water has a free surface at this point²⁹ (i.e. not under pressure), yet much of the downstream network on the Kırkçeşme line is higher than 34 m asl. The long section in fig. 2 shows the variation in ground level

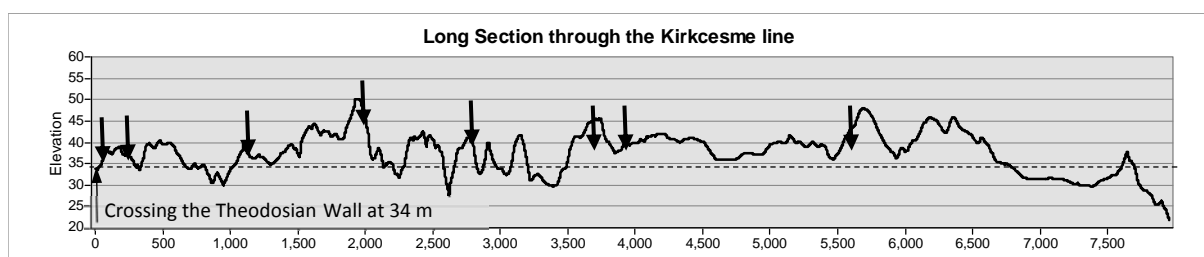


Fig. 2. Ground profile through the Kırkçeşme line within the city, from the crossing point at the Theodosian Wall (left) towards the Topkapı (right) using a digitised version of Çeçen's 1999 map on a 3D model of the city based on contours from Müller-Wiener's 1977 (supra n.20) map. Arrows indicate approximate locations of çeşme (fountains) that are positioned above the 34-m crossing level at the Wall.

along the route of the main Kırkçeşme line from the Land Walls to the east of the Topkapı Palace; several fountains along the route are higher than the established 34-m baseline, an arrangement that is physically impossible and leads us to question some of the assumptions made regarding the system. Given that much of the route within the Land Walls is above an elevation of 34 m,³⁰ we must conclude that the structure at the crossing of the Land Wall is either a branch off the main line or has been located on maps incorrectly. The water must arrive at a higher elevation than was previously believed. This therefore removes the constraint of assuming that the Hadrianic Line also arrived around this level, and we can progress with the assumption that the Hadrianic Line reached the city at an elevation above 34 m.

City routes – Hill Three – northern, southern or both – the Tezgaçılar Kubbesi structure

²⁶ Tursun Bey, *The History of Mehmed the Conqueror*; Gilles, *De Bosporo Thracio, Libri III*, 2.3, both quoted in Crow, Bardill and Bayliss (supra n.1) 242-43.

²⁷ Maps of all the Ottoman systems are reproduced in K. Çeçen (ed. C. Kolay), *İstanbul'un Osmanlı Dönemi Suyolları* (Istanbul 1999).

²⁸ A.F. Andréossy, *Constantinople et le Bosphore de Thrace, pendant les années 1812, 1813 et 1814, et pendant l'année 1826* (Paris 1828) pl.2, with J. Crow, "Water and the creation of a new city," in Magdalino and Ergin (supra n.10) 111-24.

²⁹ Çeçen (supra n.27), 104.

³⁰ Ground-level is an imperfect proxy for pipe inverts since pipes could be buried, but the presence of fountains on or close to the Kırkçeşme route and above 34 m in elevation indicates that the pipes were running near to the surface at these points.

The next question is the route taken after the channel crossed the valley between Hills Four and Three. Previously³¹ the Hadrianic Line was drawn at a low elevation (already sitting below 30 m elevation at the valley) and could only follow the northern path, taking a sinuous route around the spurs of Hills Two and Three. However, the Ottoman Kırkçeşme system, positioned significantly higher, splits at this valley, with a branch to the north and the main line to the south, to arrive at the platform between the first two hills near the middle of the Hippodrome.³² The shape of Hills Two and Three makes this southern route shorter and the gradient of the slopes traversed is shallower, which from an engineering perspective would be easier to construct (compare the original route in fig. 3 and the new route in fig. 4).

The splitting point of the Ottoman Kırkçeşme system (see fig. 3) is the Tezgaḥçılar Kubbesi. It has been identified as originally Roman,³³ with Ottoman repairs and alterations. Although adjacent to the Bozdoğan Kemerı, it is 15 m lower, indicating that this structure was not part of the Valens Line. Thus if the original structure was Roman, it would be associated with the Hadrianic Line. Sitting on the modern 40-m

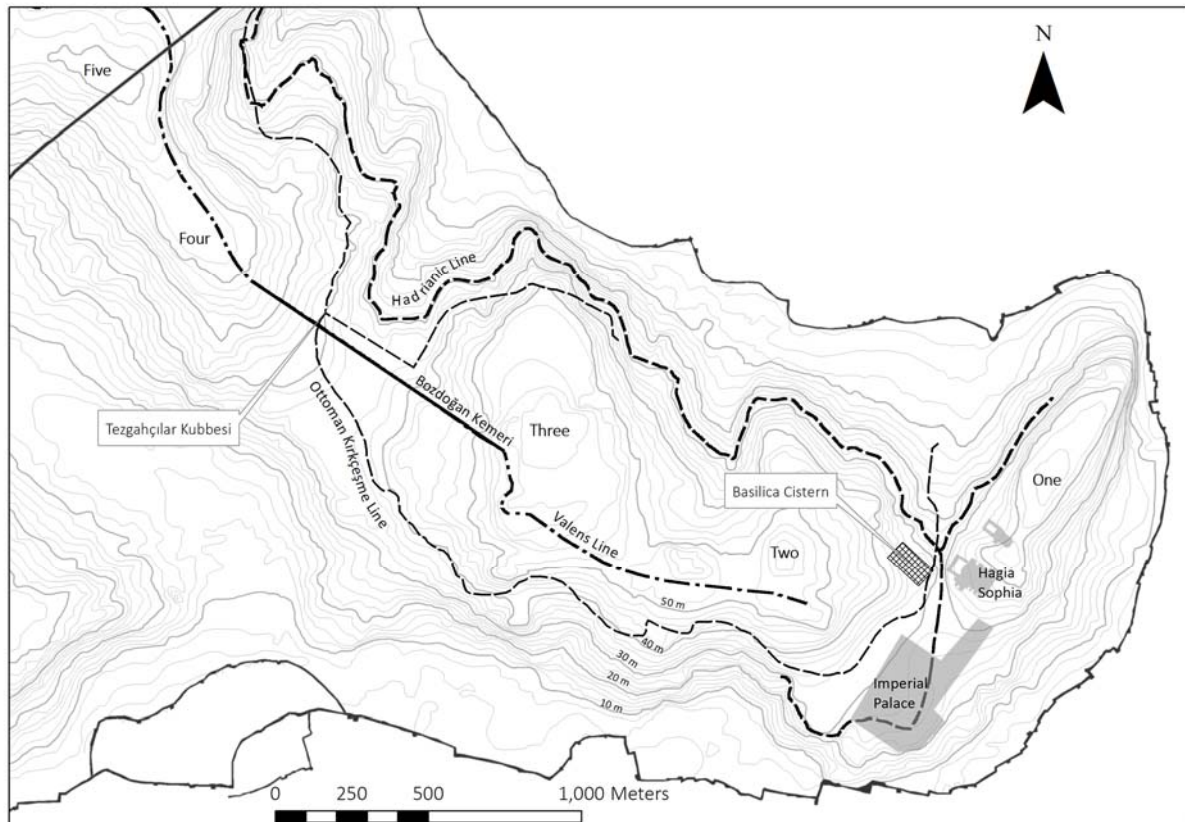


Fig. 3 Hills Three and Four, the Bozdoğan Kemerı and the Tezgaḥçılar Kubbesi. The Ottoman Kırkçeşme line is after Çeçen (supra n.28) maps 30-33; the Hadrianic and Valens Lines shown are from Crow, Bardill and Bayliss (supra n.1) maps 12-15.

³¹ Crow, Bardill and Bayliss (supra n.1) Maps 14-15.

³² Çeçen (supra n.27) Maps 30-33.

³³ Çeçen (supra n.1) 215; Çeçen (supra n.28) 105-6; and included in Altuğ (supra n.15) 426-27 as belonging to the Early Byzantine period. Although Crow, Bardill and Bayliss (supra n.1) 116 indicate that the early dating of this structure should be treated with caution, K. Dark and F. Özgümüş, *Constantinople: archaeology of a Byzantine megapolis* (Oxford 2013) 127 with pl. 2, identify this structure as a Byzantine cistern that has been uncovered by modern work, rather than a control structure that has been buried over time. The plan included in Altuğ ibid. 427, indicates an access to the structure c.2.5 m below the present ground-level.

contour, the structure is buried up to its roof and is c.5 m deep, putting the channel invert at an elevation of 35 m asl. We believe that the Kırkçeşme system can be used as a reasonable proxy for the Hadrianic Line: as it could take the northern or southern route around Hill Three, the Hadrianic Line was also capable of taking either route. This assumption is strengthened by the indication that the Ottoman Kırkçeşme system may re-use an older structure that belonged to the Hadrianic Line.³⁴

It is difficult to conclude if the Hadrianic Line split in two, like the Ottoman system, or merely crossed to the southern route. As the original town of Byzantium was not extensive and did not extend over the northern slopes of Hill Three, there would be little to justify the more complicated construction. However, this area was densely populated in the days of early Constantinople, which may have justified alterations to the existing arrangements, perhaps associated with the rebuilding of the line towards the end of the 4th c. Two of the city's 4 Nymphaea are located in regions IV and V (on the N slopes of Hill Two), and could perhaps have been supplied by the Hadrianic Line; yet even though they are located on the N slope of the hill, it would be possible for a southern branch to feed this area, as the Ottoman system illustrates.³⁵

The Basilica Cistern: endpoint of the Aqueduct of Hadrian

If the water supply entered the city from the N side of the peninsula and did not cross to a southern route in the valley between Hills Three and Four, the position of the Basilica Cistern becomes important: either the aqueduct ran on the slope above it, which would push the elevation up towards 40 m asl, or the Basilica Cistern was constructed on the line of the Hadrianic channel, meaning it would have run at c.32-36 m asl at that point, with the Basilica Cistern becoming the terminal point of the line. This carries implications for structures we believe were fed by the Hadrianic Line. Both the Zeuxippos Baths and the Imperial Palace are situated beyond the Basilica Cistern and its construction as a terminal point of the Hadrianic Line would effectively cut off their supply. We know that the Zeuxippos Baths continued to operate as baths until at least 713 and the Imperial Palace continued to be occupied, so that if the water supply was cut off considerable work would be required to re-route supplies from the Valens Line. However, this only applies if the Hadrianic Line took the northern route into the city; the southern route allows supplies to be maintained to relevant structures, including the Basilica Cistern.

During the Avar siege of the city in 626, the Valens Line was cut, preventing water from flowing until its repair in 765/6.³⁶ That the city survived for 140 years without this major source suggests that the flow in the Hadrianic Line was significant and also that it was accessible and capable of supplying key structures. The Hadrianic Line was not a channel that had been truncated and relegated to backup status in time of severe summer drought; it was a fully functioning system that enabled the city of Constantinople to survive a major attack on its infrastructure.

It would appear that, at least in later years, the Basilica Cistern was connected to the water system at its SE edge, close to the Hagia Sophia. A sluice control connected to the Basilica Cistern was reported in front of the Hagia Sophia³⁷ and a channel was revealed during construction of the tourist exit from the

³⁴ It is also worth noting that the N and S branches of the Ottoman Line are unequal; the N branch, wrapping around the steep slopes of Hill Three is relatively short. On the other hand, the S branch wraps around the S slopes of Hill Two and Hill Three, and continues round to supply also the N slope of Hill Two, which may be an indication of the difficulty of construction on the N slope.

³⁵ For the *Notitia Urbis* and the city's districts, see B. Anderson, "Social clustering in 5th-c. Constantinople: the evidence of the *Notitia*," JRA 29 (2016) 494-508; P. Magdalino, "Neighbourhoods in Byzantine Constantinople," in F. Daim and J. Drauschke (edd.), *Hinter den Mauern und auf dem offenen Land, Leben in byzantinischen Reich* (Mainz 2016) 23-30.

³⁶ Theoph. *Chron.* AM 6258, quoted in Crow, Bardill and Bayliss (supra n.1) 236.

³⁷ Forchheimer and Strzykowski (supra n.10) 55. Gilles (K. Byrd, *Pierre Gilles' Constantinople. A modern English translation* [New York 2008] 101) reports seeing the inflow to the cistern, described as a large pipe and clearly high up the cistern wall, but does not indicate the location of the inflow.

cistern in the 1980s.³⁸ Today, no inlets or outlets to the cistern are known. While none of this evidence is conclusive, it builds a picture of the advantages of a southern route into the city.

Channel in the grounds of Hagia Sophia

During excavations in the W courtyard of the Hagia Sophia, remnants of the earlier Great Church were discovered, along with a street, running roughly SE-NW which had a large 2.2 m-wide channel running beneath it.³⁹ Recent explorations of the tunnels and chambers beneath Hagia Sophia and its surroundings have revealed a complex network of channels (including the 2.2 m channel), although the original function of these structures remains uncertain.⁴⁰ The channel running beneath the street in the W courtyard of Hagia Sophia is generally assumed to be a sewer,⁴¹ but our newly-suggested southern route makes it feasible to identify the channel with the Hadrianic Line, flowing northwards along the NE slope of Hill One.

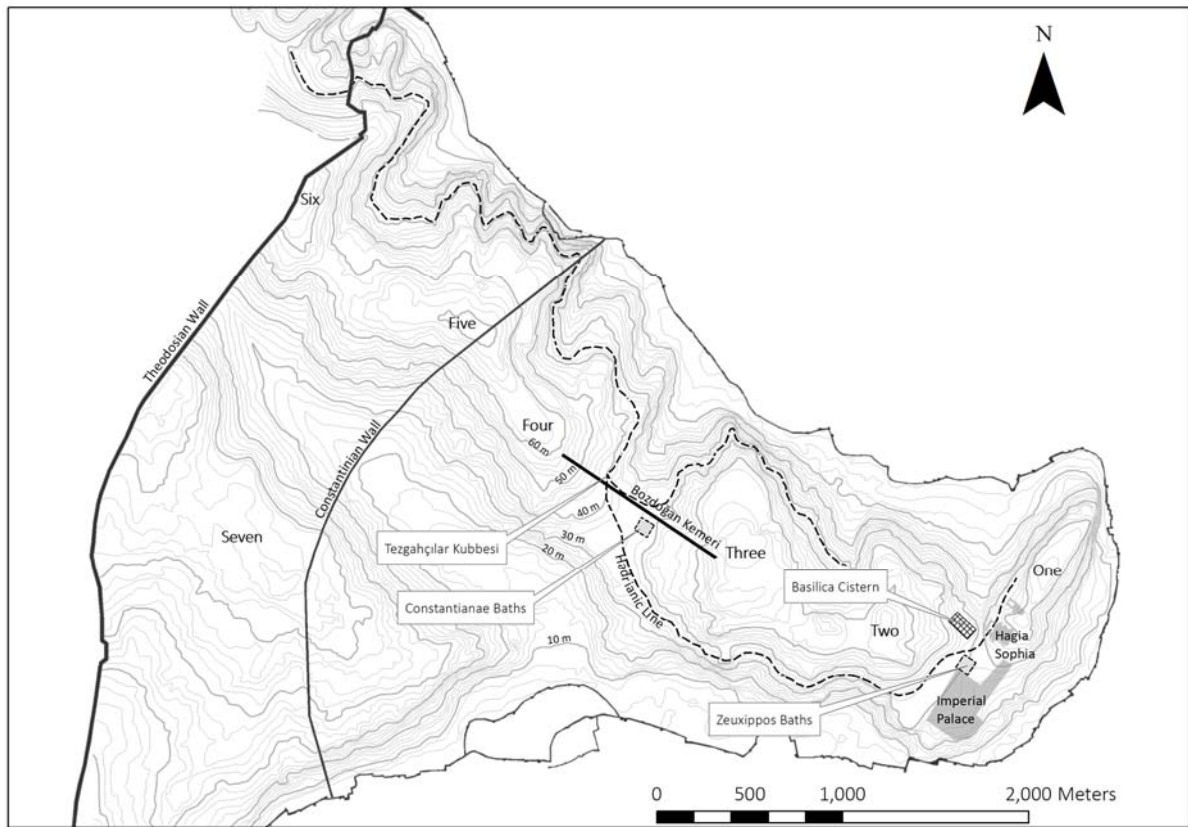


Figure 4: Suggested route of the Hadrianic Line within the city.

Summary of suggested route of the Hadrianic Line

³⁸ Çeçen (supra n.1) 25-27 photographed the channel, described as coming from the Hagia Sophia distribution centre, and associates the same channel with two deep wells in the grounds of the Topkapı Palace. These Ottoman structures may have been constructed around an older Byzantine-era well, as reported in H. Tezcan *Topkapı Sarayı ve Çevresinin Bizans Devri Arkeolojisi* (Istanbul 1989), 241-246.

³⁹ A. M. Schneider, *Die Grabung im Westhof der Sophienkirche zu Istanbul* (Berlin 1941) pl. 2. It is not clear if this channel should be linked to the channel described in n.38 above.

⁴⁰ C. Özkan Aygün, "New findings on Hagia Sophia subterranean and its surroundings," *Byzantinistica*, 2 ser., 12 (2010) 57-77.

⁴¹ By Schneider (supra n.39) 3-4; J. Bardill, *Brickstamps of Constantinople* (Oxford 2004) 27-28.

- The line is probably higher than previously thought when crossing the Land Walls, as the Ottoman system levels, previously used as a proxy are inconsistent.
- At the valley between Hills Three and Four, the Hadrianic Line was at a level sufficient to cross the saddle of the valley; this opens up the possibility of a southern route into the city.
- The differences in topography of the N and S slopes of Hills Two and Three make a southern route into the city shorter and more straightforward to construct.
- At the platform area between Hills One and Two, the Hadrianic Line was high enough to feed the Zeuxippos Baths.
- The location of the Basilica Cistern and the structures known to be fed by the Hadrianic Line make a southern route into the city more favourable.

As shown in fig. 4, the route proposed for the Hadrianic Line crosses the Theodosian Wall at a level of about 39 m asl. At the valley between Hills Three and Four, the line hugs the flank of Hill Four, passing through the structure later called Tezgahçılar Kubbesi. From here, the channel may branch, with the main branch being the southern one which traverses the valley and follows the contours on the S flanks of Hills Two and Three, bringing water to the head of the N-facing valley around the harbour. When the town became Constantinople, this southern branch continued to supply many of the key sites in this part of the city, and a northern branch may have been added, extending from Tezgahçılar Kubbesi into the densely populated flanks of Hill Three.

2. Aqueduct of Valens: supply to the new city

The Aqueduct of Valens was built in two phases during the early days of the new city when not only the population was increasing but also the area occupied by the city was expanding. This expansion generally moved upwards and outwards from the old city of Byzantium, incorporating a number of hills that could not be served by the Hadrianic Line. Maximising both the elevation of the channel and the area served would have driven the choice of route for the new line. The engineers would aim for a route that minimised the length of the channel and the complexity of construction. The Valens Line was constructed before the cisterns associated with it: the line arrived in the city in 373 and the first major cistern, the Aetius Cistern, was constructed in 421. We do not know whether the cisterns were planned in advance and influenced the aqueduct route but, as they had to be connected to one of the aqueducts in order to be filled,⁴² it is reasonable to assume some degree of proximity between cistern and aqueduct. The siting cisterns would have been influenced by a number of factors, however, including available space, topography and downstream connections. Thus we should exercise caution in using the location of a cistern to define the location of the aqueduct.

Evidence for the route

Although there is more physical evidence that may be associated with the Valens Line than there is with the Hadrianic, the interpretation of some of this evidence is difficult. The most obvious (still-visible) evidence is the aqueduct bridge crossing the valley between Hills Three and Four. Now called Bozdoğan Kemer, it is a clear indication the aqueduct followed a route along the high ridge of hills within the city. Once thought to carry the Hadrianic Line, the bridge has been confirmed as belonging to the Valens Line.⁴³ Although the ends of the bridge have been lost, we have its alignment and channel elevation (57 m at the W end).⁴⁴ The remaining physical evidence is more scarce and less conclusive. A recently

⁴² The volume of most cisterns is too large to be fed exclusively by a rainwater-harvesting system, as the catchment area required to provide worthwhile amounts is so large as to be unfeasible.

⁴³ Following K.O. Dalman, *Der Valens-Aquädukt in Konstantinopel* (Bamberg 1933). In 1985 C. Mango (supra n.18) 20 suggested attribution to Hadrian, but was more cautious in 1995 (supra n.1, p. 12.) See Crow, Bardill and Bayliss (supra n.1), 13-14 for dating and attribution.

⁴⁴ Measured at arch 1 by Dalman *ibid.*, quoted in Crow, Bardill and Bayliss (supra n.1) 120.

discovered channel upstream of Bozdoğan Kemerı might be associated with the line. A number of brick channels, stone channels and marble pipes observed along the modern Ordu Caddesi and Divan Yolu Caddesi align closely to the ancient main street of the city, the Mese, but these structures have not been subject to detailed study, some being identified as water channels, some as drainage structures.

Channel in Baş Müezzın Sokak

A large vaulted brick channel, (figs. 5 and 8) running perpendicular to Baş Müezzın street is a strong candidate for the Valens Line upstream of Bozdoğan Kemerı.⁴⁵ The channel is at the highest point of the street, close to where it crosses Boyacı Kapısı Street. At just over 2 m wide and c.2.5 m tall, the brick channel was capable of carrying high flows. Hydraulic mortar (which would be evidence of the channel being part of the aqueduct) is not recorded, but the channels position on top of the ridge effectively eliminates the possibility of the structure being a drain. The location indicates that the aqueduct would follow a route on the peak of the ridge or its S side, rather than the northern side as previously shown (see fig.1). The northern route around Hill Five is longer than the southern, but it does pass alongside the Aspar Cistern. We propose that the main channel took the southern route around Hill Five, and that a branch was constructed at the time of the construction of the Aspar. The ground level where the point the channel was found is high, c.67.5 m asl. From fig.5 it is apparent that the channel is positioned just beneath the road surface; thus we estimate the channel invert level at 64-64.5 m asl. One km farther upstream the channel must pass the saddle between Hills Six and Five, adjacent to the Aetius Cistern. As the modern ground level at this saddle is about 62-63 m asl, the channel must have crossed on a raised substructure or used an inverted siphon. Downstream from the channel in Baş Müezzın Sokak the land drops to Bozdoğan Kemerı, requiring the channel to drop some 7 m over 500 m – a rapid drop which could create undesirable flow conditions particularly directly upstream of a bridge. The sizeable cistern (38 m x 26 m) on the N flank of Fatih Camii⁴⁶ points to a solution: the channel could use this cistern as a settling basin, entering at a relatively high gradient but exiting at a gradient and level suitable for crossing the bridge. The large volume of water would provide a buffer to allow the transition from a relatively steep channel to a relatively shallow one.

Sewers, storm drains or water channels – resolving the evidence in proximity to the Mese

Although vaulted channels and pipes ran below the line of the ancient Mese, their exact purpose is not immediately clear. Evidence of the pipes and channels found between Forum Tauri (Bayezit) and the Milyon are outlined in **Error! Reference source not found.**; their locations are illustrated in fig.7.

[Figure 5. removed from open access manuscript as copyright held by third party]

Fig. 5. Channel found beneath Bas Muezzin Sokak (Istanbul Municipal Archive)

Drainage and water-supply are both gravity-fed, but the design features differ. As smaller channels feed into progressively larger ones, drainage accumulates flow like a river system, whereas water supply distributes flow from larger into smaller channels. Ideal flow conditions also differ. In water supply, maximising elevation is crucial, with the result that shallow gradients and slow velocities are normal. Drainage requires steeper gradients and faster velocities for the rapid removal of wastewater to prevent deposition and odour.

We know that the channels discovered at the Forum of Constantine and under the Arch of Theodosius (Table 1, no. 5) were at approximately the same elevation. If they were connected, the gradient between

⁴⁵ Baş Müezzın Sokak lies northwest of the Fatih Camii, the site of the Holy Apostles church.

⁴⁶ The partially collapsed cistern measures at least 38 m x 26 m. It has some evidence of an inflow channel in one corner: Altuğ (supra n.14) cistern 137, pp 414-15.

them was extremely shallow.⁴⁷ These poor flow conditions, exacerbated by the parallel channels being interconnected, make it unlikely that they were sewers carrying human waste. Both the flat gradient of the channels – if they were connected along the Mese – and the interpretation of the double channel as redundancy (allowing access for repair whilst maintaining an essential flow of water) support the hypothesis that the channels form part of the water supply. On the other hand, the position and arrangement of the channels suggest they are not water-supply infrastructure:

[Figure 6. removed from open access manuscript as copyright held by third party]

Figure 6: Pipe excavation west of Kara Mustafa Paşa Medrese (DAI Istanbul) KB 2871).

⁴⁷ E. Mamboury, “Les fouilles byzantines à Istanbul et dans sa banlieue immediate aux XIX^e et XX^e siècles,” *Byzantion* 11 (1936) 253, assumed that the channels were drains running continuous from the Augusteion to the Lycus near the Forum Bovis and used this as a proxy for the line of the Mese. Because of the change in elevation, it is most likely that the line of the sewer was continuous but actually sloped in two directions, draining to both the east and the west, with the split located somewhere between the Fora of Constantine and Tauri.

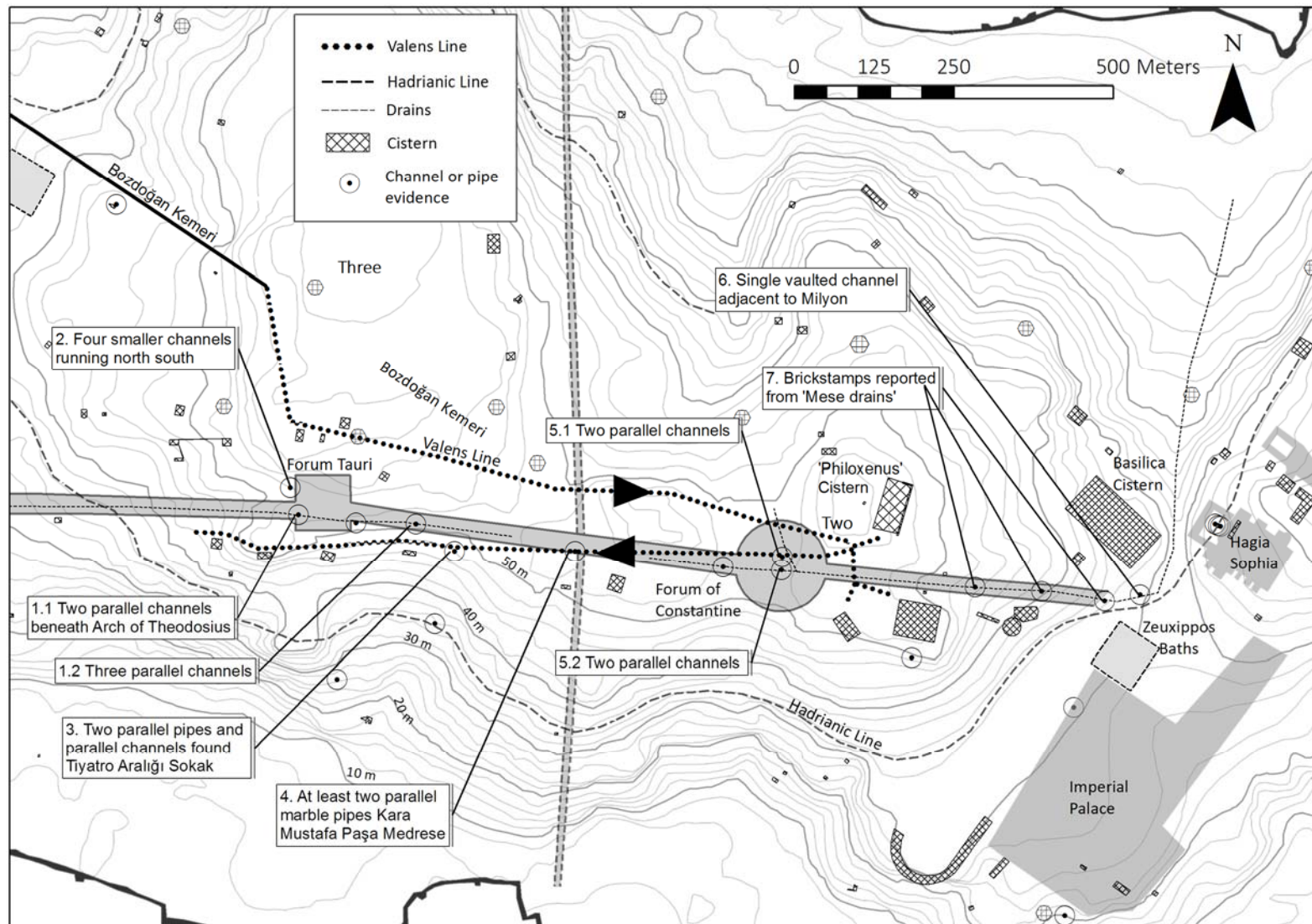


Figure 7: Detail of suggested route around the Mese for the Valens Line and the Hadrianic Line, with suggested drain routes.

TABLE 1
EVIDENCE OF PIPES AND CHANNELS IN THE VICINITY OF THE MESE
(see fig.7 for precise locations)

<i>Ref</i>	<i>Location</i>	<i>Description</i>
1	Forum Tauri	The excavations of the Theodosian Arch in the 1920s uncovered two parallel channels running approximately E-W through the Arch of Theodosius. The channels were described as possible water channels. ¹ These channels are in close proximity to two further discoveries: 200 m east of the Theodosian Arch 3 parallel channels were uncovered; between these two excavations, a third found a single channel. ²
2	Forum Tauri	An excavation slightly north of the arch revealed four channels running approximately N-S. ³ These are not of a size to be associated with the channels crossing Bozdoğan Kemerli, but could possibly be drains that discharge into the larger channels beneath the Mese.
3	Tiyatro Aralığı Sokak	Offset to the south of the line established by the channels at Forum Tauri is a series of pipes shown in a photograph of an excavation in Tiyatro Aralığı Sokak. ⁴ It shows large marble pipes, described as running in an E-W direction. The two-part photo also shows what may be 2 parallel channels (described in the caption as galleries) which could also be associated with the water supply. To judge from the photograph, the pipes are similar to those now found in the grounds of Hagia Sophia; the relationship between pipes and channels is not clear.
4	Near Kara Mustafa Paşa Medrese	East of Tiyatro Aralığı Sokak, the excavation in fig. 6 found more marble pipes west of Kara Mustafa Paşa Medrese, running in two (possibly more) parallel lines. ⁵ There are no indications of channels in this excavation, although it is not clear whether it extended across the full width of the road.
5	Forum of Constantine	Two sets of 2 parallel vaulted channels discovered north and south of the Column of Constantine. One set of channels is described as constructed in brick, the other in stone. ⁶ The brick-built channels could perhaps be associated with the channels seen passing under the Arch of Theodosius.
6	Milyon	From Müller-Wiener and an excavation near the site of the Milyon, this comprises a single vaulted channel with a branch going in the direction of the Hippodrome. ⁷
7	Various	Bricks with brickstamps removed from vaulted structures along the E end of the Mese, between Atık Ali Paşa Mosque and Firuz Ağa Mosque. ⁸

¹ S. Casson, D. Talbot Rice and A.H.M. Jones, *Second report upon the excavations carried out in and near the Hippodrome of Constantinople in 1928 on behalf of the British Academy* (London 1929) 40.

² Müller-Wiener (supra n.20) 261, fig. 294, unmarked on the diagram but noted as D in the caption, midway between A and E.

³ R. Naumann, "Neue Beobachtungen am Theodosiusbogen und Forum Tauri in Istanbul," *IstMitt* 26 (1976) 117-41.

⁴ The excavation occurred in 1975; photographs are included in Altuğ (supra n.13) 42, fig. 3.15.

⁵ Müller-Wiener (supra n.20) 268-69, figs. 303 and 305.

⁶ E. Mamboury, "Les fouilles byzantines à Istanbul et dans sa banlieue immédiate aux XIXe et XXe siècles," *Byzantion* 11 (1936) 254.

⁷ Müller-Wiener (supra n.20) 216, fig. 245.

⁸ Reported in Bardill (supra n.42) 77-78 from the notes of Mamboury.

they do not take the highest route available; they flow beneath the Mese, making supply to street level difficult; and the connection with Bozdoğan Kemerli entails a 90° bend at the end of the bridge and again at the Arch of Theodosius, a needlessly complex arrangement.

We can be more certain about the pipes found at Kara Mustafa Paşa Medrese (**Error! Reference source not found.**, no. 6). Their location, slightly west of the lowest point of the ridge between Hills Two and Three, could indicate that they formed a flat inverted siphon, using pressure flow either to overcome the drop in elevation or to pass through an area with insufficient ground-cover to incorporate a channel. This would be unnecessarily complicated and costly⁵⁶ for a storm drain, particularly when there is a clear option to drain down the slope towards the sea. However, as Roman engineering situates a channel to minimise loss of elevation, additional costs for pipes and siphons are justifiable. Thus we can identify the pipe finds at Tiyatro Aralığı Sokak and west of Kara Mustafa Paşa Medrese as part of the water supply.

The channels beneath the Mese (Table 1, nos. 1, 5 and 7) are not sewers and are unlikely to be water supply. While their generous proportions are consistent with storm drains, the street collection and guttering (of which there is very little evidence) would need to be large, regular and efficient for the channels to be used at capacity.

Our solution is far from certain but it offers an arrangement of both water-supply and drainage structures that reconciles the available evidence. The channels referenced as nos. 1 and 7 and the S portion of no. 5 are assumed to be drains (fig. 7). The channel at no. 1 flows west into the Lycus or Harbour of Theodosius while the channels at nos. 5 and 7 flow east towards the Augusteon, discharging around the Prosphorion Harbour. The Valens Line is expected to maintain a position on the high ground north of the Mese, distributing water to the Cistern of Philoxenus⁵⁷ before doubling back along the Mese, initially in the channels at the N portion of no. 5, then at no. 4 in pipes whilst crossing under the road, and discharging into a channel at no. 3 to feed the cisterns on the S side of Forum Tauri.

Suggested Route of the Valens Line

Although the evidence for the Valens Line is difficult to interpret with certainty, we conclude as follows:

- Based on the discovery of a large channel in Baş Müezzini Sokak, we propose that the main route for the Valens Line was on the S side of Hill Five, although a branch to feed the Aspar Cistern is likely to have been added when the cistern was constructed in 459.
- The channels running beneath the Mese are unlikely to be the main Valens Line, which probably ran on the higher ground north of the road. However, the large stone pipes found midway between the Forum of Constantine and the Forum Tauri are almost certainly associated with the water supply.

In fig. 8, the Valens Line enters the city on the N slope of Hill Six at c.65 m asl, taking the southern route around Hill Five to the bridge between Hills Four and Three. The line follows the highest ground towards Hill Two. Inverted siphons may have been necessary to maintain maximum elevation. The largest cistern north of the Mese is the Philoxenus, which may have acted as a kind of *castellum* for the Valens Line. It is uncertain whether the Valens Line continued further east towards Hill One, but there

⁵⁶ This forms part of our current project *Engineering the water supply of Byzantine Constantinople*, in which manpower rates from G. Pegoretti, *Manuale pratico per l'estimazione dei lavori architettonici* (Milan 1863-64) are compared for equivalent lengths of hollowed-out pipe and masonry channel.

⁵⁷ The cistern on Bab-ı Ali street, which is identified as the Cistern of Philoxenus by J. Bardill, "The Palace of Lausus and nearby monuments in Constantinople: a topographic study," *AJA* 101 (1997) 69-75.

was almost certainly a branch which crossed the Mese and fed the cisterns on the S slopes of Hills Two and Three, including the Binbirdirek cistern.

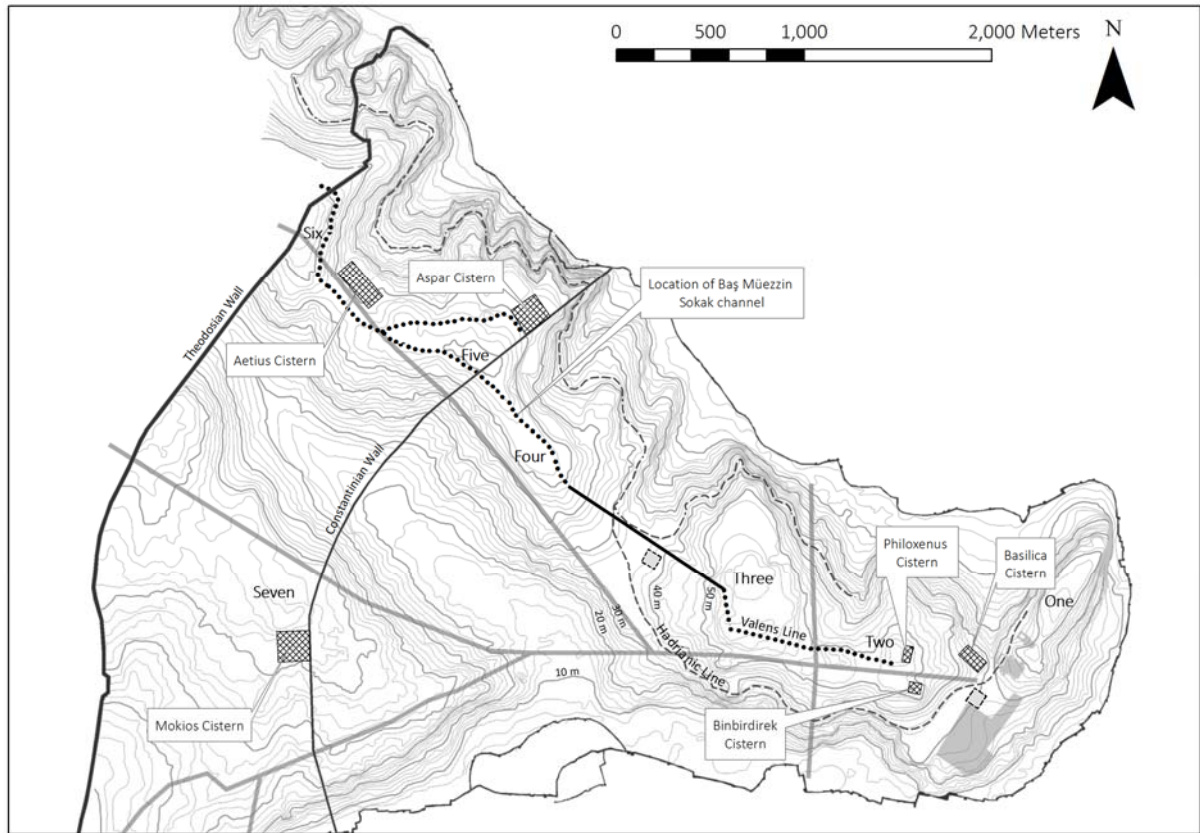


Fig. 8: Suggested route of the main Valens Line

3. Cisterns

Scholars have long been interested in the cisterns of Constantinople, but only relatively recently have studies shown how numerous they were. This is perhaps unsurprising: although present elsewhere in the Roman Empire, cisterns were not a standard tool in water supply nor known to be combined in networks. So many cisterns marks a significant change in Constantinople's water-supply strategy, which had begun in a typical way with an aqueduct bringing water. After the construction of the colossal Valens Line, water-supply investments focused on cisterns within the city. From meeting increased demand for water by obtaining more water (as was the strategy in Rome), the strategy shifted to managing and storing available resources.

The two most recent and comprehensive works on the cisterns of Constantinople doubled the number of known cisterns in Constantinople to c. 160.⁵⁸ By combining these studies, the current investigation has established that there are 211 Byzantine-era cisterns. This new list allows us to examine the rôle of cisterns and develop ideas about how water was distributed across the city.

⁵⁸ In Crow, Bardill and Bayliss (supra n.1) 144-55, Bardill created a bibliographical concordance of 161 cisterns, with two of these on the Galata peninsula. Altuğ (supra n.14) 142-457 includes a catalogue of 158 cisterns on the historical peninsula.

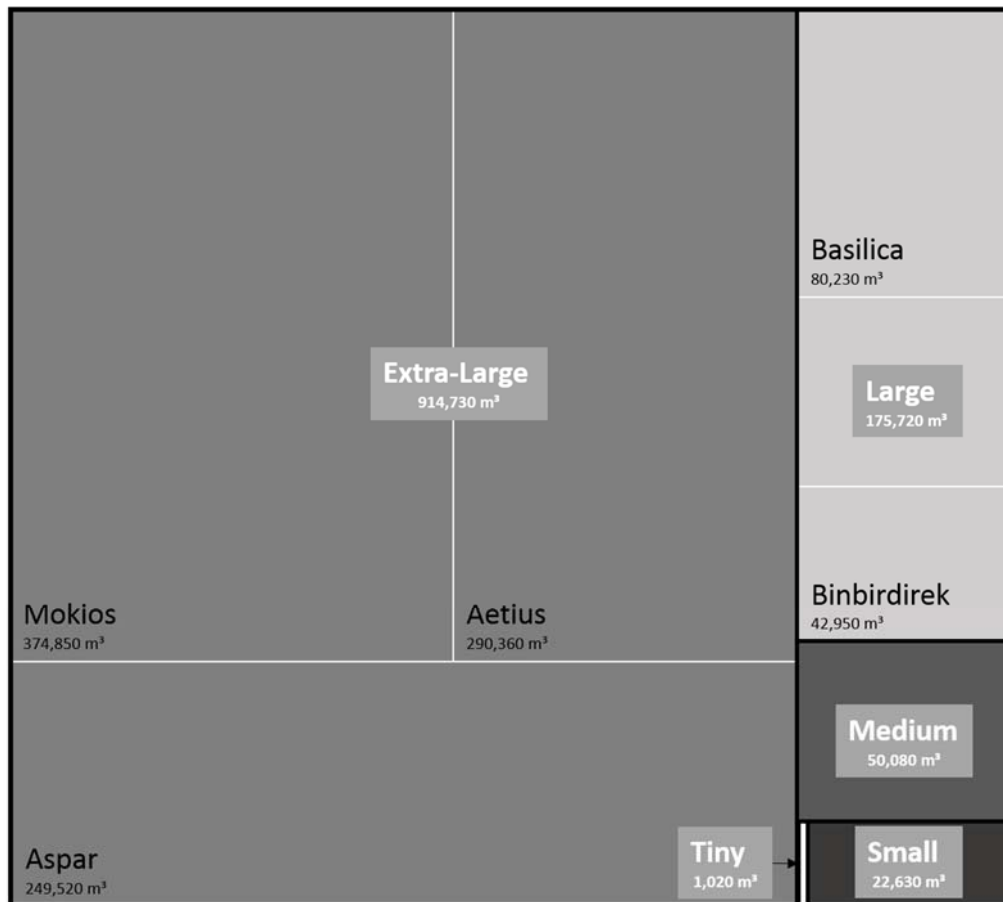


Fig. 9: Distribution of known volume of cisterns (diagram created in R package version 2.4-1 [2016] of M. Tennekkes, Treemap Visualization, available at <https://CRAN.R-project.org/package=treemap>; adapted for clarity).

The range of cisterns

Cisterns in Constantinople range from the smallest, traditional structures that were probably rainwater-harvesting systems belonging to individual households, to colossal open-air structures capable of holding several months' worth of supplies. Fig. 9 illustrates how the total storage volume of over 1.1 million m³ is distributed among the 101 cisterns providing sufficient data to calculate or estimate their storage volume. Over 100 cisterns without sufficient data are omitted, including some believed to be large, such as the Modestus and Philoxenus Cisterns. The majority of storage is on the periphery of the city in the three open-air cisterns of Aetius, Mokios and Aspar; next, in the heart of the old city, come the largest of the covered cisterns, the Basilica and Binbirdirek. Other cisterns add a negligible amount to the storage capacity yet clearly serve an important rôle in distributing water from the aqueducts and possibly from the larger cisterns. Fig 10 shows the spread of cisterns across the city. It shows that there must have been a complex network of distribution beyond the main lines of the two aqueducts. The majority were constructed after the completion of the Valens Line, not to replace the aqueducts but to assist in serving the population. We do not fully understand their purpose nor how the stored resource was managed, but quantifying and locating the cisterns and the aqueducts that fed them within the city is an important first step.

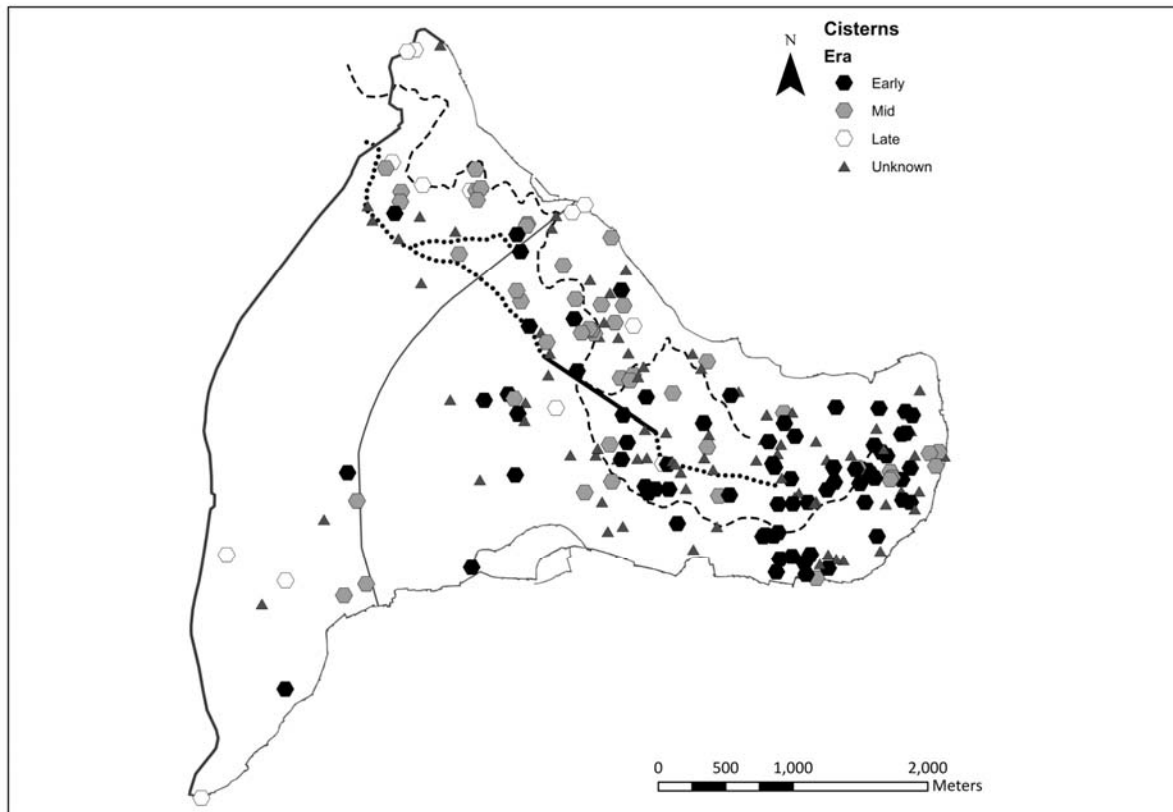


Fig 10: Distribution of early (4th-7th c.), mid (8th-12th c.), late (13th-15th c.) and unknown cisterns.

Some cisterns have been dated into three broad periods - early (4th-7th c.), middle (8th-12th c.), late (13th-15th c.) - and period unknown.⁵⁹ From this data we can see that, although cistern construction was reduced in later periods, it did continue, suggesting that the water-supply system was continuously adapted to the needs of the city as the population rose and fell, population centres moved, and cisterns were damaged. Cisterns distinguish Constantinople's approach from that of other major Roman cities. Though space precludes detailed study of how they were connected in a distribution network, we consider the possible arrangement of cisterns and channels on a smaller scale with two cases where the need to feed cisterns raises important questions about channel routes, water sources and the use of lifting mechanisms.

Case-study 1. Water-supply to cisterns on Hill One

Hill One is separated from Hill Two by a valley some 10 m deep (fig. 11). Largely within the precinct of the Topkapı Sarayı, it is one of the best-preserved and least developed areas, well endowed with cisterns, some sizeable. The available catchment area is too small to sustain the cisterns using a rainwater harvesting system making it a puzzle how a substantial flow could be delivered to them. The first option is that the Valens Line crossed the valley from Hill Two to Hill One, but it is difficult to find a clear route between the hills, for this area of the city was congested with large buildings and public spaces. The shortest route is blocked by the Hagia Sophia, while the northern route is obstructed on Hill Two

⁵⁹ Altuğ (supra n.14) provides dates for some of the 158 cisterns in his catalogue. The additional cisterns from the concordance in Crow, Bardill and Bayliss (supra n.1) have been included in the "unknown period" category.

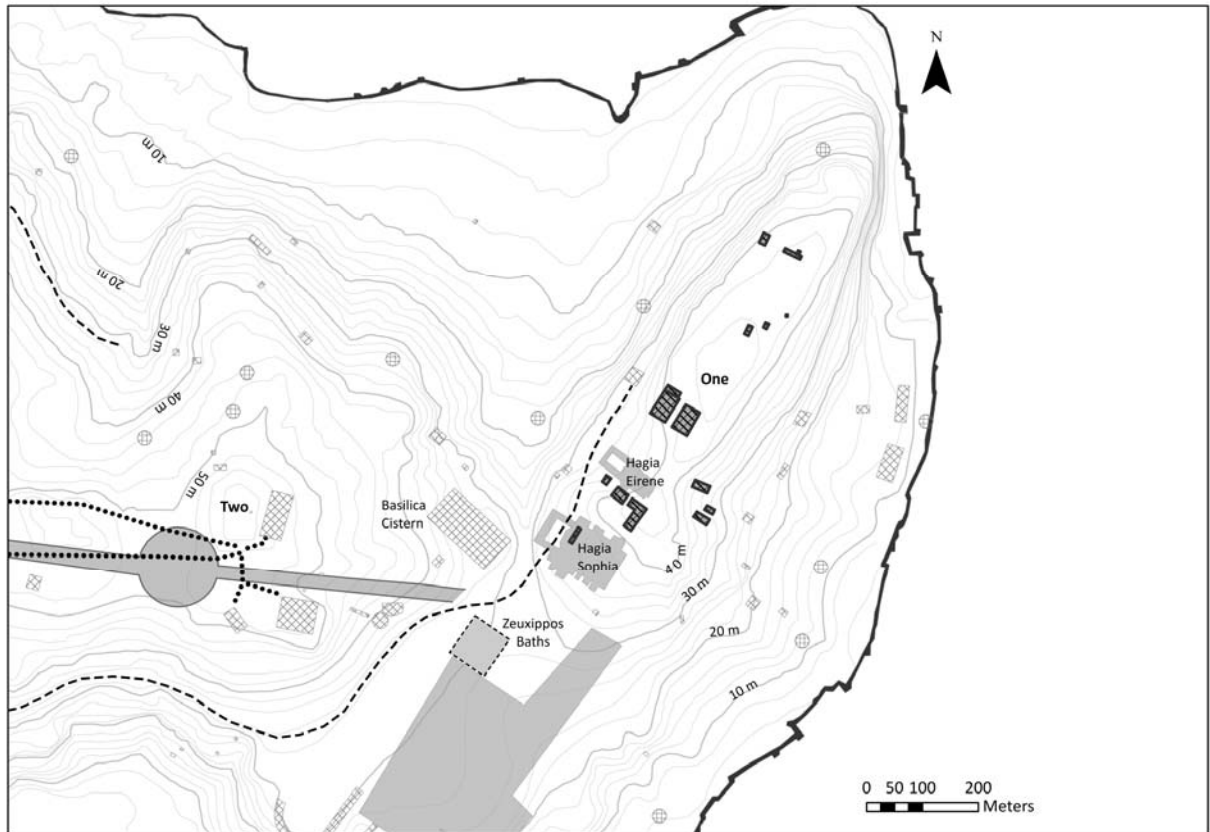


Fig. 11. The water-supply to Hill One is uncertain. The cisterns highlighted are at an elevation that would require water to be lifted or to cross from Hill Two using a bridge or inverted siphon.

by the Basilica and on Hill One by the Hagia Eirene and the hospital which sat between the two Great Churches. If the cisterns were fed by the Valens Line, it probably crossed to the south of the Hagia Sophia, traversing the Augusteon before turning north by 90°. Yet this route is also congested, and the complexity of it suggests a bridge or arcade rather than a siphon. The second option is that water was lifted from a low level by a mechanised device. Such an arrangement was used during the Ottoman period in the grounds of the Topkapı Sarayı: a well was linked to a channel at a low level which fed it with water.⁶⁰ As mentioned above, the Ottoman system may update a similar Byzantine one, with the channel connecting to what we now believe to be part of the Hadrianic Line.

Case-study 2. Feeding the Mokios Cistern

Mokios, an isolated open-air cistern on Hill Seven, is the largest known in Constantinople. Constructed in the early 6th c. and measuring 170 x 147 m and 15 m in depth, it provides almost a third of the known storage volume within the city. It must have been fed by an aqueduct but the aqueduct source is uncertain. Perhaps Mokios was fed by a branch from the Valens Line, splitting off close to the Aetius Cistern and following a path back out of the Theodosian Wall, crossing the Lycus valley, and then re-entering the city on the N slope of Hill Seven (fig. 1),⁶¹ or the Lycus valley may have been crossed by an inverted siphon. Alternatively, Mokios may have been fed by a separate line taking water from the Halkalı springs. These were tapped by the later Ottoman system and are closer to the city than the Belgrade Forest or the numerous mountain springs used, respectively, by the Hadrianic Line and the Valens Line. It is difficult to conclude which option was preferred, but it

⁶⁰ Özkan Aygün (supra n.40) 58; and, Tezcan (supra n.38) 241-46.

⁶¹ Proposed in Crow, Bardill and Bayliss (supra n.1) Map 12.

seems unlikely that a water source so close to the city would go unused. Modern estimates of the yield of the Halkalı springs are relatively low,⁶² and the complexity of the Ottoman systems constructed to capture them perhaps shows why the springs were not used as a primary source for the whole city, but it does not exclude them as a supply to the area around Hill Seven.

Conclusions

Although the remaining evidence is fragmented and unclear, by considering it within the framework of a functional water-supply system that corresponds to engineering expectations we can offer a fuller interpretation of the city's water infrastructure.

We have proposed new routes for the city's aqueducts. The Hadrianic Line probably crossed from the N slopes of the peninsula to the S slopes between Hills Four and Three at a higher level, arriving close to the Hippodrome before passing the Zeuxippos Baths and Basilica Cistern. Beyond, the channel might be associated with the 2.2 m wide channel running beneath the grounds of Hagia Sophia along the NW slope of Hill One.

The Valens Line is expected to take a different route, with the main line running south of Hill Five, rather than alongside the Aspar Cistern. Farther downstream, the situation is less clear. The Valens Line probably ran north of the Mese, maintaining height before discharging into the Philoxenus Cistern. A number of branches may have crossed the Mese to feed the Binbirdirek and other cisterns on the S side, conveyed in the stone pipes found at two points near the Mese. The remaining channels running beneath the Mese could be associated with drains, although questions about their size and design remain.

Cisterns are more numerous than previously thought, with 211 associated with the Byzantine era. Their number and spread throughout the city show that they were key to the operation of the system; they also show that there was a network of considerable complexity connecting the aqueduct routes just described with the cisterns, and connecting the cisterns with the people.

The extent of the water-supply system is not yet understood; some significant questions remain, particularly on how water was supplied to Hill One and to the Mokios Cistern on Hill Seven, but a detailed study of the connections between cisterns, aqueducts and the population is now possible.

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⁶² Dalman (supra n.43) quoted in Mango (supra n.1) 10, notes a yield of only 6000 m³ per day for Halkalı. K. Çeçen 1991 *Halkalı Suları* (Istanbul 1991) 30, noted 16 separate lines as part of the Halkalı system, with a combined flow of 4212 m³ per day.